

A Silvicultural Guide to the White Pine Working Group



Ontario

Ministry of
Natural
Resources

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1.0 MANAGEMENT OBJECTIVES

The white pine (Pinus strobus L.) working group should be managed to produce high-quality products in the form of sawlogs and veneer in the shortest possible time. Where markets for them exist, pulpwood and energy stock should be produced from logging residues, thinnings, and intermediate cuttings. To achieve these objectives, a rotation of 100 years on site class 1, 120 years on site class 2, and 140 years on site class 3 is required.

The maintenance and improvement of wildlife habitat for prominent game species should be considered when selecting regeneration and tending procedures for white pine. The need for deer cover in recognized yarding areas may require an extensive adjustment of rotation age, cutting cycle, and silviculture system to ensure protection and continuity of the cover species.

Aesthetics is an important consideration in the management of white pine because its range coincides with the major recreation areas in Ontario. The retention of white pine for aesthetic purposes is particularly important adjacent to travel routes, especially along the shorelines of major lakes. The practice of leaving unmanaged decadent reserves of varying widths should be replaced by a more flexible and practical policy of managing the reserves (Hough, Stansbury, et al., 1973).

Site protection on the shallow, lighter soils can be more important than timber production. White pine is well suited to these sites because of its seeding ability, development, and form of root system. It responds well to modified cutting and, in many cases, abundant and partial shade are all that is required to ensure regeneration and hence site protection.

2.0 MANAGEMENT DECISIONS

The management of white pine in Ontario should fall into one of the following categories:

1. A long-term commitment to intensive forest management

This is the category of management into which most of the white pine stands in the province will fall as the intensity of management increases. It involves a full commitment to a high level of applied silviculture from the time the stand is established until the trees are harvested. This category will include not only natural stands but most artificially established stands as well.

Intensive management should take place mainly on sites that are relatively easy to moderately easy to manage and where blister rust (Cronartium ribicola) and white pine weevil (Pissodes strobi Peck) are at a reasonably controllable level. At this stage of management intensity in the province, sites that are more highly productive but costly to manage should be avoided. Most of the silvicultural effort should occur on those sites designated for intensive management.

2. Maintenance of the white pine component

This category of management usually applies when white pine is mixed with other species or is a component of some other working group. It rates low as far as silvicultural effort is concerned. It may involve one or both of the following two conditions:

- Stands of white pine containing other species where improvement cutting is recommended to maximize growth and quality in the pine component before it is harvested. This is considered as a transitional form of management since white pine stands within this category may later be transferred to intensive management (category 1) or liquidated (category 3).
- Stands where white pine is a relatively minor component of another working group are usually found on sites that support medium- to lower-class tolerant hardwoods. Here an attempt is made to perpetuate the pine component in the stand by leaving residual seed

trees and applying supplementary site preparation. Expenditures to maintain the pine under these conditions are relatively low. Sometimes the objective is to maintain the pine component for aesthetic purposes.

3. Liquidation of white pine where future management of this species is not recommended

This category of management applies in the following circumstances:

- where insects, disease, or competition problems make investment in white pine management uneconomic;
- where the site is considered to be better suited to the production of other species;
- where white pine is growing beyond the geographical limitations as specified in policy directive FR.

4. Conversion to white pine from another working group

This category of management applies to sites that once supported white pine but, owing to a history of exploitation of the pine or lack of proper management, now support fewer valuable species. Converting a percentage of these sites by planting them to white pine is an option that should be seriously considered.

3.0 SILVICAL CHARACTERISTICS INFLUENCING MANAGEMENT DECISIONS

3.1 Habitat

White pine occurs alone, in mixtures with red pine (Pinus resinosa Ait.) and jack pine (Pinus banksiana Lamb.), or in association with poplar (Poplar spp.) and white birch (Betula papyrifera Marsh.) after a fire. Such associations will persist longer on dry, less productive sites than on fresher, richer sites. Also, on fresher, richer sites the natural successional trend will be towards an increasingly stronger component of white spruce (Picea glauca (Moench) Voss), balsam fir (Abies balsamea (L.) Mill.), or tolerant hardwoods, depending on which is locally present.

Most commonly found on fine sands and loams, white pine will also grow on heavier soils. However, natural regeneration is restricted as a result of hardwood competition.

Superior growth is achieved on fresh to moist well-drained soils, yet it occurs over a wide range of moisture conditions from swamps to dry sand plains and rocky ridge tops.

White pine, unlike red pine, is quite tolerant of high-lime soils. The optimum pH range is said to be between 4.7 and 7.3 (Wilde, 1966).

3.2 Reproduction

The white pine cone takes two years to develop. Early in June of the first year, pollination takes place. Cone ripening occurs during August and September of the first year, with seed dispersal occurring in September and October. The seed is usually dispersed no farther than a distance equivalent to the height of the tree, although seed is occasionally found extending 61 m within the stand and 229 m in the open.

The frequency of good cone crops varies from three to five years but can take up to ten years. Seed years become less frequent as the trees reach maturity.

The minimum seed-bearing age is 15 to 20 years and the maximum age is around 250 years; the optimum seed-bearing age occurs between 50 and 150 years. Cone yields in a good year average 1.8 hectalitres per tree.

3.3 Establishment

Most white pine stands were established as a result of spontaneous fires that exposed mineral soil. The burns created a good seedbed and eliminated vegetation that competed with pine regeneration. In contrast, recurrent fires associated with logging and clearing often destroyed young pine stands before they reached seed-bearing age. White pine is more tolerant of shade than is red pine, and it will continue to maintain maximum height growth at a level of 45 per cent of full light. This tolerance of shade enables trees to be underplanted and results in thinner leaders which are less susceptible to white pine weevil attack.

The white pine seed has an embryo dormancy that is broken by natural stratification in autumn and early spring. Therefore, seed sown in late spring would have to be artificially stratified. As shown by Wilson and McQuilkin (1963), seed germinates best on moist mineral soil, polytrichum moss, or short grass of light to medium density. Germination occurs at temperatures between 20°C and 30°C.

Following germination, young seedlings are highly vulnerable to climatic and biotic hazards such as drought, insolation, freezing temperatures, flooding, and rabbits and mice. In addition, logging often creates conditions unsuitable for abundant natural regeneration. The relatively slow growth of the white pine during the first five years puts it at a disadvantage in competing with other species, particularly hardwoods.

3.4 Development

Root grafting is a phenomenon which delays mortality of trees threatened by competition (Bormann, 1966). Fomes annosus (Fr.) Karst. can be transmitted by root grafts and non-target trees killed by root-graft connections to chemically treated stems.

A natural deep-rooting tendency makes white pine windfirm. On shallow soils it is windfirm when the root system spreads over the surface of obstructions and penetrates pockets of deeper soil. Only on shallow soils without pockets of deeper soil or on sites with a high watertable is white pine susceptible to windthrow, especially after partial logging.

When white pine is grown in association with black walnut (Juglans nigra L.), its height growth is depressed from the toxic effect of the chemical juglone emitted by the walnut. (This characteristic can be used to the advantage of the walnut in a mixed white pine/walnut plantation where the pine, after shading out the lower branches of the walnut, gradually dies and drops out of the mixture after about 25 years (Johnston, 1977).)

3.5 Tree Improvement

The ability to hybridize with other five-needle pines provides scope for the production of hybrids that are resistant to blister rust and white pine weevil. Significant improvements can also be obtained in three characteristics through selection of seed source (Zsuffa, 1975).

3.6 Height Growth

In natural, pure, or mixed stands of red and white pine, red pine grows faster at first but is overtaken by white pine at ages ranging from 40 years on better sites to 85 years on poorer sites. In mixed red pine/white pine plantations, white pine characteristically lags behind red pine.

4.0 ECOLOGICAL BASIS FOR SILVICULTURE

The commercial range of white pine extends across the Great Lakes - St. Lawrence Forest Region and the Deciduous Forest Region and into the southern part of the Boreal Forest Region in Ontario (Rowe, 1972). The northern extremity of the range follows a line drawn from just south of Lake Abitibi to the northern tip of Lake Superior, up to Lake Nipigon, and to the Manitoba border at Lake of the Woods.

White pine grows on a wide range of soil conditions but is most common on the drier, sandy sites. In Ontario, white pine sites on the Precambrian Shield are characterized by deep moulded tills on the tops of broad drumlinoid ridges, on shallow dumped tills, on the top and sides of low granitic ridges, and on outwash plains and terraces where the soil ranges from sand to gravel. South of the Precambrian Shield white pine grows well on loams, silts, and lacustrine deposits.

The physiographic site types on the Precambrian Shield are intimately associated and can be encountered within a few hundred metres of each other.

4.1 Outwash Plains

The deep granitic sands of various textures and moisture regimes found on these sites are usually dominated by sweet fern (Comptonia peregrina L.) and blueberry (Vaccinium sp.) after a fire, followed by pioneer tree species such as red and white pine, jack pine, trembling aspen (Populus tremuloides Michx.) and white birch. Intolerant hardwood species do not grow well here and do not offer the same degree of competition to pine as they do on more productive sites. Often, jack pine and red pine, in time, fall behind white pine in growth. In the northern part of the range, as the stand develops, balsam fir, white spruce, and black spruce (Picea mariana (Mill.) B.S.P.) gradually occupy the site along with white pine, which is the only pine that will persist in any quantity on this site.

Although less productive than the deep moulded till sites, outwash plains are a preferred site for managing white pine because of the relative ease of establishment and lack of serious competition.

4.2 Shallow Dumped Till

The pattern of succession on these sites, although somewhat similar to that on the outwash plains, differs in that competition to pine seedlings is more aggressive and difficult to control. Aspen and birch grow better on these tills, impeding the growth of pine regeneration, particularly that of jack and red pine. Spruce and balsam fir also infiltrate the site more readily after a disturbance, as do underbrush and scrub maple. The longevity and reproductive ability of white pine assure it of representation in the spruce-fir climax but usually not to the same extent as on outwash landtypes. The productivity of the pine on these rather fragile sites is generally lower than it is on the outwash plains. The site class for white pine would normally be rated site class 2 or poorer (Plonski, 1960). Ground vegetation that helps identify the site is aster (Aster macrophyllus L.) and wintergreen (Gaultheria procumbens L.) in the southern or predominantly hardwood regions of the Precambrian Shield, and wintergreen alone towards the northern or predominantly coniferous regions.

4.3 Deep Moulded Tills

The successional trend here differs from that on the other sites described in that red pine and jack pine are seldom present. The pioneer hardwoods offer increased competition, and ground vegetation is more numerous and aggressive than on the other sites. Tolerant hardwoods, spruce, and balsam fir are also much more competitive than in the previously described landtypes. The longevity and superior height of the white pine allow scattered remnants of pine to survive among the other more tolerant species, but the dense subordinate layer of hardwoods on the ground prevents natural regeneration of white pine from obtaining a foothold unless the successional trend is severely disrupted by fire or windthrow.

Although this is one of the more productive sites for growing white pine, it is also one of the more difficult and costly sites to manage for this species.

Deep-till sites are usually relatively flat or gently rolling and less broken than shallow dumped-till sites. On many of them the remaining pine has been logged and the only indication that pine was once present are the large stumps left from previous logging operations that removed all pine, leaving no seed source.

The vegetation types that tend to identify the above sites are Aster-Corylus on the dry to moist slopes, Cornus-Maianthemum on the moist lower slopes, and Trillium on the somewhat dry to moist drumlin slopes.

4.4 Loams and Clays

The deep, fresh loam and clay soils in the southern part of Ontario that have not been cleared for agriculture will not be considered as part of the permanent white pine group.

In the past, these sites produced some of the best pine, but without major disturbances they have reverted to the tolerant hardwood working group through natural succession. Because of the heavy competition, the management cost of retaining them in the white pine working group is prohibitive. However, some of the best white pine plantations in Ontario are produced on those loam and clay loam sites which have been cleared for agriculture and are, for various reasons, available for planting.

5.0 HARVEST CUTTING AND NATURAL REGENERATION

Most of the white pine stands existing in Ontario today are of fire origin. With better forest-fire control and harvesting methods that concentrate solely on extraction, with little or no regard for the re-establishment of a new stand, it would be just a matter of time until the white pine working group would cease to exist as a viable source of sawlog material. To maintain this working group, harvesting methods must be applied that take into full consideration the silvical characteristics of the species and a thorough understanding of its environmental constraints.

Since white pine is only moderately tolerant of shade and can withstand only limited competition, it must be managed under some form of even-aged-management system; uneven-aged management by the selection system is not acceptable.

5.1 Clear Cutting

Clear cutting involves complete removal of the old stand in blocks or in strips wider than 40 m, relying upon artificial regeneration or natural seeding for the new stand.

As planting is expensive, clear cutting and planting should be used only where other alternatives are not available and benefits will justify costs. Examples of situations in which clear cutting and planting are appropriate include those involving overmature pine with a low capability of seed production, those in which there are infrequent seed years, and those in which the seed source is from tall, slender trees subject to breakage.

Steep slopes subject to erosion (Smith, 1962), excessively dry or exposed sites where germination and survival of seedlings would be in question, and richer or moister sites where competition is a consideration are situations to be avoided. One marked advantage to clear cutting and planting is that it allows the stand to be replaced by genetically improved stock, including stock resistant to white pine blister rust and white pine weevil.

5.2 Seed Tree System

The seed tree cutting system is used in Ontario where a low-cost, extensive form of silviculture is advocated. In its simplest application it is used in an attempt to maintain white pine as a component of a mixed-wood stand of pine and hardwoods.

Between 12 carefully selected, uniformly distributed pine trees per hectare on dry sites and 25 trees per hectare on moist sites (Horton, 1962a) are left as a seed source. North Bay District favours leaving 35 trees per hectare (Miller, pers. correspondence, June 1981). Best results are obtained where logging coincides with a good seed year. On mixed-wood sites enough shade protection from residual hardwoods is expected to prevent a build-up of white pine weevil. Seed trees should be superior specimens, full-crowned, well-formed, and windfirm. Trees with obviously inherent malformations should be removed to avoid genetically inferior regeneration (Horton, 1962a).

The shallow-till site is the most suitable site condition for seed tree treatment as seedbed conditions here are generally quite receptive for regenerating white pine without the need for mechanical site preparation.

A more intensive variation of this treatment involves the use of supplementary mechanical site preparation to create a greater area of seedbed. The extra treatment may be required where logging takes place during winter months or where competition is expected to seriously impede white pine regeneration.

The seed tree method could also be applied to the outwash plain landtype with an excellent chance of obtaining satisfactory white pine regeneration. However, this method is not normally recommended here, since a uniform shelterwood system achieves at least equally good regeneration and carries with it a reduced risk of weevil damage and losses from exposure.

5.3 Strip Shelterwood

By definition strip shelterwood cuts are alternate or progressive strips up to 40 m in width. Beyond this width the method is considered a form of clear cut.

Strip shelterwood works best on outwash plains and on shallow tills. On most of these sites supplementary site preparation should be unnecessary. Where conditions exist that require site preparation, such as on moist pockets where vegetative competition would smother the pine seedlings, the treatment should be timed to coincide with a seed year.

Strips should be used only where topography will allow them to be lined out at right angles to the prevailing winds and still have skidding and logging disturbance confined to the strip. Sites to be avoided are those where favourable conditions for growing pine are interspersed with conditions that are unsuitable for pine reproduction. These include moist sites, bog edges, seepage areas, silted basins and terraces, and well-drained sites in which hardwoods prevail (Horton, 1962b). In these conditions a uniform shelterwood system is a better choice.

The strip shelterwood system may also be used on deep-till sites but this method is expensive, since extensive site preparation and subsequent tending are required to bring the pine through. A mixed pine/hardwood stand would be a more acceptable objective as the cost of a complete conversion to pine is prohibitive.

There is a marked correlation between the width of the strip and the incidence of weevilling. The wider the strip, the greater the chance of weevil damage. Likewise, the amount of regeneration tends to be heavier in the narrower strips. Wide strips often tend to show a saucer effect, with plenty of regeneration along the edges but with the regeneration gradually diminishing towards the centre of the strip. This phenomenon is particularly noticeable on the strip cuts in Algonquin Park.

Where aesthetics is a consideration, strip cuts are less desirable than is the uniform shelterwood system.

5.4 Uniform Shelterwood

The uniform shelterwood system is the preferred method to use on outwash plains and shallow sites. It is the system that is most likely to succeed, as it provides the best seed source and the best protection against intolerant competitors. Reproduction is achieved under the protection of the old stand by means of partial cuttings resembling thinnings. To obtain regeneration in a previously

unmanaged stand, the first cut, the preparatory cut, is designed to develop thrifty seed-bearers and to remove the seed source of other competitive species. However, if the stand has been previously managed by systematic thinning, the development of good seed-bearers should have already been achieved so that this step may not be necessary.

The next step, the seeding cut, should coincide with a seed year during which skidding, supplemented by site preparation, has been done to prepare the seedbed. By the time the stand is ready for a seeding cut it should support about 300 trees per hectare. The seeding cut should reduce it by 40 to 60 per cent (Lancaster and Leak, 1978).

Before the seeding cut, advance regeneration of hardwoods may be controlled by herbicide application (Lancaster and Leak, 1978) or by controlled burning (Van Wagner and Methven, 1978).

The removal cut usually takes place in one operation, five to ten years after the seeding cut. If, however, a sufficient number of seedlings have not become established, the overstory removal should be delayed and another seeding cut made or site preparation measures taken to improve seedbed conditions.

6.0 SITE PREPARATION

For the purpose of this guide, site preparation is defined as a disturbance of the forest floor and the top soil to create suitable conditions for natural regeneration, seeding, and planting. Although mainly done mechanically, site preparation is also achieved by prescribed burning and by chemical application.

The need for site preparation increases as the seedbed becomes less receptive as a result of accumulations of litter and invasion of competitive vegetation.

6.1 Mechanical

Mechanical site-preparation equipment is used both for preparing the site for planting and direct seeding and for creating a seedbed for natural regeneration of white pine. J.S. Miller (1978) describes the various pieces of equipment used for site preparation in the re-establishment of white pine in the Algonquin and Northeastern regions in 1976. Table 1 summarizes the type of equipment listed in this survey, where it was used, and comments on its performance. Since this survey was conducted the Leno Cultivator, an intermittent scalping-type scarifier, has been used to prepare sites for natural regeneration of pine following a seeding cut. The relative ease with which this unit can be manoeuvred around residual trees and the degree of exposure obtained have shown this to be a promising tool for white pine management.

The Silvicultural Equipment Reference Catalogue for Northern Ontario (Smith, 1980) is an excellent document for detailed information on most of the equipment referred to above.

Obviously there is no one piece of equipment that will suit every situation. Probably the best advice at this stage is to keep up to date on new equipment and techniques as they become available and to keep informed about the experiences of other districts which have tested new equipment.

6.2 Prescribed Burning

The extensive stands of white pine which covered this province at the time of its settlement were the results of wild fires. Controlled burning trials at the Petawawa National Forest Institute (Van Wagner and Methven, 1978) have proven to be a practical alternative to wild fires in preparing sites for natural pine regeneration.

Controlled burns at the proper time and at the right intensity have the capability of burning off enough of the duff layer and reducing brush and small-tree competition to create conditions conducive to white pine seedling germination and establishment.

Some of the highlights of prescribed-burning research at Petawawa revealed the following:

TABLE 1
Site Preparation Used for Promoting White Pine
in the MMR Algonquin and Northeastern Regions in 1976

<u>Equipment</u>	<u>Where Used</u>	<u>Comments</u>
Straight blades on 42 h.p. tractor	After a seeding cut in a uniform shelterwood system	Treated deep soiled sites only. Cost: low
Straight blades and rock rakes on 180 h.p. tractor	Backlog areas of fresh glacial till in preparation for planting Sandy outwash plains after a seed tree cut	Low production Cost: high Vegetation controlled for three to five years but site tends to dry out resulting in mortality and poor growth Cost: average
V-blade with replaceable foot on 95 h.p. wheeled skidder	On deep fresh to wet silty loam soil interspersed with bedrock outcrops in preparation for planting	Very manoeuvrable; acceptable job of removing slash and mixing mineral soil with organic soil; makes deep ruts in wet silty loam Cost: average
V-blade on tractors ranging from 97 to 270 h.p.	In heavy brush competition or logging debris in preparation for planting and seeding	Very manoeuvrable; very well suited for small clearings or partial cut-overs; better shearing action than straight blades Cost: average
Young's teeth mounted on 180 h.p. tractor	Where light mixing of the soil required on a seed tree cut	Manoeuvrable and versatile; creates good seedbed conditions for planting, limited by heavy slash rocks and high stumps Cost: high (research)
Flanged barrels and spiked anchor chains (three barrels, three chains) drawn by 103 h.p. skidder	On shallow sandy soils and sandy loam boulder tills with numerous rock outcrops in connection with seed tree and uniform shelterwood cuts and in preparation for planting	Organic and mineral soil well mixed; tended to ride over slash; loaded barrels required a skidder in the 100 DBHP range Cost: low to average

- To avoid damage to the established pine stand it is best to burn stands that are 80 years old or older.
- The preferred stage for burning is in an untouched stand before the first partial cut.
- When hardwood brush is plentiful two fires are required, the first in the spring before flushing and the second after the leaves are out. The two fires should be run in consecutive years for the best results.
- If the understory is pure hardwood, fire behaviour is uniform and predictable and control is relatively easy.
- Balsam fir understory complicates fire behaviour, particularly when present as clumps where the fire may crown and damage the pine overstory.

In addition to removing underbrush in an established pine stand, fire can reduce underbrush and logging slash on clear-cut areas in preparation for planting. The technique for this type of prescribed burn is described in detail in the Prescribed Burning Manual published by the Ontario Ministry of Natural Resources in 1980.

6.3 Chemical

Herbicides are sometimes used as a preplanting site preparation treatment to destroy herbaceous or brush competition. Under these conditions systemic herbicides such as 2,4-D and 2,4,5-T, or a combination of the two are applied in relatively heavy concentrations of 2.24 kg/ha (Struik, 1978) or more to eliminate or "set-back" competing vegetation before the area is planted. The use of systemic herbicides has the advantage of removing competition for a sufficiently long period of time to enable planting stock to become established without having to disturb the soil, an important factor under certain site conditions. Another obvious advantage to the preplanting application of herbicides, as opposed to applications for release, is that the chemical does not come into contact with the planting stock. This is particularly important with white pine, which tends to be sensitive to damage from these chemicals.

Grass and weed control is important in plantations on old farmland, particularly on sites where herbaceous competition is a critical deterrent to planting-stock growth and survival. Campbell (1981) describes four herbicides currently used in Ontario to control weeds which are applicable to white pine and in plantations. These herbicides are simazine, amitrole, glyphosate, and paraquat.

Simazine is a soil sterilant that controls weeds when it is washed down into their rooting zone by rainfall. Since it normally does not penetrate deeper than 5 cm, it should not affect deep-rooted weeds and young trees. The application rate of simazine will vary, depending on soil type, from 4.5 kg/ha on light sandy soil to 6.8 kg/ha on soil with a high organic or clay content.

Amitrole is absorbed both through roots and through foliage and can be translocated upward and downward in the plant. Since the primary entry is via foliage, the plant should be 8-20 cm in height before it is sprayed. For lasting effect amitrole must be used in conjunction with simazine.

Glyphosate is absorbed through foliage and translocated to the roots, which means that it is effective against perennial weeds. Since it kills only existing vegetation and does not affect weeds germinating from seed, it should be combined with simazine for residual control. Glyphosate is effective against hardwoods and conifers if sprayed on foliage and green bark during the growing season. Pine and spruce are sufficiently tolerant to glyphosate that it can be sprayed over top of them for conifer release in the summer after they have hardened off.

Paraquat is a completely non-selective herbicide that kills only green tissue with which it comes into contact above ground. Therefore plants with a well-established root system will grow back again after treatment. As it is not a persistent chemical, it must be used with simazine for lasting control.

Table 2 gives the recommended mixtures, rate of application, and timing for each of the herbicides or herbicide combinations described above (Campbell, 1981). For further details on the action and use of these herbicides refer to Old Field Chemical Site Preparation (Revised March 1981) by R.A. Campbell, Pest Control Section, Ontario Ministry of Natural Resources.

TABLE 2
Old Field Chemical Site Preparation for Pine and Spruce

HERBICIDE(S)	RATE kg. of active ingredient per sprayed hectare	TIMING
simazine	4.5 - 6.7*	late fall or early spring** until vegetation is 10 cm tall
simazine	4.5 - 6.7*	in spring when vegetation is 7.5 - 20 cm tall
+	+	
amitrole	1.1	
simazine	4.5 - 6.7*	in late summer to early fall when vegetation is still actively growing or in spring when vegetation is taller than 20 cm
+	+	
glyphosate	2	
simazine	4.5 - 6.7	in spring when vegetation *** is taller than 20 cm
+	+	
paraquat	1.1	

- * Rate varies with soil type — 4.5 kg on light sandy soil to 6.7 kg on heavy clay soil.
- ** Simazine alone, even if applied in late fall or early spring, may not control deep-rooted perennials.
- *** Because paraquat tends only to top-kill vegetation, the only place where it would be used in place of glyphosate is when spraying has to be done at a particular time (e.g., with a sprayer-planter) and when heavy rain (which would nullify the action of glyphosate by washing it off) is imminent (paraquat does not wash off).

7.0 ARTIFICIAL REGENERATION

7.1 Planting

In general the same rules that apply to the care, handling, and techniques of planting other conifer species have application to the planting of white pine. Several points, however, should be noted.

Although white pine will not stand sites as dry as those on which red pine can be planted, it does appear to have a greater tolerance towards limey soils than does red pine.

White pine is best planted on medium to fine sands and sandy loams, leaving the drier sandy sites for red or jack pine. On the heavier soils and low-lying sites, white pine tends to be less subject to white pine weevil damage than it is when planted in the open on hot, dry, sandy plains.

Avoid planting white pine on thin soils over limestone such as occur in eastern Ontario. Such sites, if they are to be planted at all, would be best planted to jack pine, European larch (Larix decidua Mill.) or white cedar (Thuja occidentalis L.). Where the soil is 30 cm or more deep, white pine can be planted on limestone soils in admixture with jack pine (Chapeskie, pers. communication). Although the extent of weevil damage tends to be overrated in southern Ontario, certain precautions should be taken to minimize this danger. Where weevil damage is a problem, spacing between rows and within rows should be reduced to 1.5 m. This close spacing helps to ensure that enough good trees are left for selection of crop trees and to force the development of straighter stems in those trees that have been weevilled. Some non-commercial thinning may be required at age 20 to 25. Access is achieved by taking out two consecutive rows and cross-rowing.

Underplanting is also recommended for white pine, as an overstory will reduce the incidence of weevil damage. The best overstory under which to plant is composed of intolerant hardwood species such as poplar and white birch. This will be discussed in more detail in the sections on "Tending" and "Damaging Agents".

Another technique that will minimize risk from white pine weevil is to plant a mixed row of white pine and red pine among alternate rows of pure red pine. As the stand develops, ensure that enough white pine are released to provide seed trees. In this way, as the stand matures, the red pine will be removed gradually to provide just enough light for the white pine to seed-in without creating conditions that favour the build-up of a weevil population. This approach will produce, in the first rotation, a crop of red pine pulpwood and poles and white pine sawlogs. In the second rotation it will produce an essentially pure white pine stand (possibly with white pine standards from the previous rotation). A variation of this mixture, preferred by some districts, involves planting three rows of pure red pine and one row of mixed red and white pine or one row of pure white pine. The recommended spacing for this type of mixed plantation would be 1.8 m x 2.1 m, with 2.1 m between rows to facilitate mechanical harvesting. This same spacing is recommended in pure white pine plantations where weevilling is not a serious problem.

Alternate rows of red and white pine have been planted successfully on drier sites where red pine will outgrow white pine. After a number of years white pine will fall behind red pine; eventually, it will disappear from the stand. In doing so, however, it will have achieved similar results to alternate-row thinning in a pure red pine stand without the cost of mechanical thinning. The spacing in a plantation of this type should not be more than 1.9 m x 1.9 m. If the spacing is greater than this, natural mortality of white pine will not occur; the pine will be suppressed but remain part of the stand. This method of alternate-row planting should be used only where a market for small red pine thinnings is not available.

Other species that have been planted successfully with white pine are European larch and tamarack (Larix laricina (Du Roi) K. Koch). The recommended spacing with these species is 1.8 m x 2.1 m.

The planting of white pine in a mixture with black walnut is a technique used in the southwestern part of the province. In this mixture the white pine is sacrificed in the interest of producing a high-quality walnut plantation.

The outside row is planted with pure white pine 2.1 m apart in the row. The next row is planted alternately with white pine and walnut 2.1 m apart. This arrangement -- a row of pure pine adjacent to a row of pine and walnut -- is repeated throughout the plantation at 2.1 m x 2.1 m.

The walnut produces a substance called juglone from the roots, leaves, twigs, and nut hulls that is toxic to most evergreens. Depending on the type of soil, walnut growth rates, and stand density, by the time the stand is 25 to 30 years old most of the nurse crop of white pine will have died. The decline of white pine should occur when the walnut has achieved 7.3 m to 11.0 m of branch-free bole. The final spacing of the walnut when the pine has disappeared will be 4.2 m x 4.2 m.

7.2 Direct Seeding

Based on the number of unsuccessful attempts to direct-seed white pine and the difficulty of obtaining a good seed supply, this technique is not recommended for use other than in closely controlled trials or experiments.

8.0 STAND ESTABLISHMENT

White pine seedlings, especially on the fresher sites, must compete with grasses, weeds, brush, and weedy plants. The relatively light competition found on the poor and dry sites is not a problem and can be beneficial in that it protects the seedlings from excessive exposure. However, where the competition is overtopping the pine and inhibiting the annual growth, release by hand tools or by selective herbicide application may be required. Small areas of plantations or natural regeneration are best released by hand, using such tools as brush hooks, axes, and brush saws, or by backpack sprayers. Although these methods, being labour intensive, are usually expensive, considerable savings can be realized by taking advantage of subsidized youth or social programs.

Aerial spraying should be used only if the pine regeneration is in danger of serious losses due to suppression and the area is large enough to warrant this type of treatment. As white pine is very susceptible to damage from selective herbicides (such as 2,4-D) during the period of rapid height growth, rate and timing of application of chemicals are both important considerations. Application rates for 2,4-D should be between 1.2 kg/ha and 1.68 kg/ha acid equivalent

(Struik, 1978). This herbicide should not be applied until after the growth of the pine has hardened off. Note that this often does not take place until late in the summer when the physiological processes of the plants to be destroyed have slowed down to such a point that application of the chemical may not produce the desired results.

In releasing white pine regeneration, it is at least as important for the herbicide to remove the understory brush competition as it is for it to control the poplar and birch oversteps. It is sometimes difficult to reach the understory when applying herbicides by aircraft as the spray is intercepted by the overtopping canopy. A second application may produce better results -- but at the risk of removing too much of the overstory and exposing the pine seedlings to white pine weevil attack. A preferred treatment for use where the site is reasonably accessible is to apply the spray by mechanical ground-application methods.

9.0 TENDING

Tending is a necessary treatment in managing white pine to ensure a quality product through the development of straight stems and rapid growth.

9.1 Cleaning and Liberation

Cleaning is defined as an operation in a young stand, not past the sapling stage, to free the best trees from undesirable individuals of similar age or size which overtop them or are likely to do so; whereas liberation is an operation to free young stands, not past the sapling stage, from the competition of older overtopping individuals. Both treatments are required in the intensive management of white pine stands and are often required on the same area. They can be done simultaneously.

Cleaning can begin as soon as the stand shows evidence of suppression but before the effects of suppression or whipping become serious. It is desirable to

delay cleaning until the pine seedlings are large enough and vigorous enough to outgrow sprouts, suckers, and shrubs (Horton, 1962a). In white pine stands this usually occurs when the pine is about 2 m tall. Ideally, only the individual stems that are directly competing for light and space need be removed, so that protection is afforded to both the young pine and the site. There has been a tendency in the past, when following this procedure, to err on the light side which means that the stand will close again in five years or less, requiring a repeat treatment. Until we are prepared to practise a high degree of intensive management, requiring several cleanings, it is best to open the stand so that the effect of the treatment will last longer -- until the first commercial thinning, it is hoped.

With a liberation cut, enough overstory should be removed to prevent the white pine from stagnating but without risking a build-up of white pine weevil. In any case, once white pine reaches a height of at least 6 m, the overstory can be removed. This is discussed in more detail under the section on "Damaging Agents".

A variety of tools can be used in cleaning and liberation activities. These include axes, brush hooks, brush saws, and chain saws. Chemicals can be used in frilling and poisoning operations or as a basal or foliar spray. Mechanical girdling (without the use of chemicals) is sometimes a preferred treatment, particularly in a liberation activity.

9.2 Improvement Cutting and Thinning

Improvement cutting is described as a special form of thinning that applies particularly to stands that have been mismanaged or not previously managed (Smith, 1962). When first managed, most pine stands in Ontario require an improvement cut. This operation, like cleaning and liberation cutting, involves the removal of clearly undesirable dominant trees that hamper the development of better individuals. In thinning, on the other hand, dominant trees are usually favoured by cutting trees in the subordinate crown classes.

The types of trees to be removed in an improvement cut include inferior species; crooked, leaning, extremely limby and otherwise badly formed trees; overmature individuals; and trees that are seriously injured. It is important that

this treatment be carried out as soon as possible in the life of a stand to prevent the stand from deteriorating further.

Crop trees should be selected during the improvement cut or early thinning stage. These trees exhibit the following characteristics: dominant or co-dominant, with a well-developed leader; a full, round, finely branched crown; dark green foliage, smooth bark, straight cylindrical stem; no stem injury or sign of disease or serious insect damage. As many trees as possible with these qualities should be chosen and stems interfering with their development should be removed periodically as thinnings, bearing in mind that at one-half rotation age there should be 740 to 1480 trees per ha at spacings of 2.4 m to 4 m.

In stands up to age 50, thinnings should be in the form of improvement cuts or cuts to anticipate mortality among the lower crown classes or to remove trees of poor form. From 50 years until the beginning of the seeding cut (about 20 years prior to the final harvest cut), chiefly co-dominants are removed in thinnings designed to free the dominants, with the operation during this period serving both to maximize diameter growth on the crop trees and as a preparation cut for seeding-in the next crop. No attempt should be made to obtain regeneration during this period.

9.3 Pruning

It has been said of white pine that there is no other species for which the financial rewards of pruning are higher or the penalties of not pruning greater (Smith et al., 1975). The penalty of not pruning is the production of a preponderance of loose-knotted, low-grade material, usually worth little more than the cost of harvesting and manufacturing.

Before any pruning is done, the first thinning, any row thinning, and the selection of crop trees should be completed. This will minimize the loss of pruned trees in subsequent thinnings.

If pruning is started early, it is recommended that about 30 per cent more trees be pruned than is required at the end of the rotation. This will compensate for mistakes in the selection and for losses (Lane, 1960). Thus, if the objective is to produce 250 to 300 crop trees per hectare, then 325 to 390 trees per hectare should be pruned.

Ideally, pruning should begin when the trees are small -- with a diameter of less than 15 cm (Campbell, 1956). At this size, branches are small, cost less to prune, and tend to heal much more quickly. However, it is still profitable to prune stems up to 30.5 cm in diameter (Horton, 1963) and even beyond this (Fedkiw *et al.*, 1959) if the trees are thrifty, growing on a good site, and are to be retained for a period of at least 40 years following pruning. In any case, pruning should not take place after the tree is 80 years old (Horton, 1963).

Live branches over 5 cm in diameter should not be pruned because of high cost, slow healing, and danger of decay.

Pruning for a 5 m log should be done in two stages, the first up to a height of 2.7 m. Hand saws, small power saws, or clippers can be used at the first pruning stage; pole saws or ladders and hand saws at the second. Cuts should be made as close to the trunk as possible to minimize branch stubs. Axes should never be used for pruning.

Between one-third and one-half of the live crown can be removed by pruning without serious loss of growth. The amount of crown that can be safely removed is subject to the restriction that at least one-third or preferably one-half or more of the total stem be live crown for best growth (Smithers, 1954).

10.0 DAMAGING AGENTS

The two most important damaging agents affecting the commercial production of white pine are white pine weevil and white pine blister rust. In some localities these insect and disease problems can be so difficult to control that it is not feasible to manage white pine on any long-term basis. In these areas a cost-benefit study in managing this species should be done before any large-scale program is undertaken. Fortunately, the areas where these problems are serious enough to discourage management are not extensive. One exception is the area west of Lake Superior where our present knowledge of blister-rust incidence indicates that no attempt should be made to perpetuate white pine other than for special purposes such as research or education.

10.1 White Pine Weevil

White pine weevil is a native insect that attacks the terminal shoot of white pine, causing a deformity in the stem. Repeated attacks render the tree useless commercially.

The white pine weevil hibernates as an adult in the litter, usually at the base of the tree on which it feeds. It emerges in the spring, usually about April, and moves to the upper portion of the leading shoot. Here it feeds, mates, and lays eggs. The eggs that are deposited under the outer layers of the bark hatch in about two weeks. The larvae move downward, feeding on the inner bark. Pupation occurs within the dead leader, and the new adults emerge during August to September. The adults feed on the bark of new and old growth, then move to the ground to hibernate during October (Horton and Bedell, 1960).

Direct control measures include hand-picking of adult weevils, application of chemical sprays, and removal of infested leaders. The latter two methods have been used by the MNR with success. Spraying the leader in the early spring with methoxychlor is recommended. When the trees are taller than 3.65 m it is usually best to use aerial application. Consider up to three successive years of spraying to reduce population to 5 per cent or less (de Boo, 1978). Hand clipping of the leader should take place in July while the larvae are still inside the shoot. The clipped leaders must be destroyed by burning.

Another control method is to trap weevils by laying out sections of pine bark on cloths soaked in turpentine. When the adult weevils emerge in the spring they are attracted to the traps; they can be collected in the early morning and destroyed before they become active. This method is used where intensive management can be practised.

White pine growing in the open are more attractive to weevils than those growing in shaded conditions. Where weevilling is a problem, white pine is best grown under a canopy of trees, at least during its early years, to prevent weevil damage. This canopy should be maintained until the tree is at least 6 m tall in order to obtain a weevil-free, and thus straight, 4.9 m log.

The best type of shade comes from old pine, because it is more attractive to the weevil than is the slower-growing young thin-barked understory (de Boo, 1978). Although investigators disagree on the amount of shade needed to obtain

satisfactory control of the weevil, a canopy that allows 50 per cent sunlight to reach the seedlings seems to be a practical compromise that does not incur an excessive loss of growth.

Private landowners who are growing white pine should be encouraged to practise weevil control.

As mentioned earlier, under artificial regeneration trees grown under close spacing of 1.5 m x 1.5 m, even though they have been weevilled, are more likely to have straight stems than those grown under wide spacing. Also, the second rotation of a properly managed plantation should be essentially weevil-free if approved silvicultural cutting practices that provide protection for the understory are followed.

10.2 White Pine Blister Rust

White pine blister rust is an introduced disease of white pine caused by the fungus Cronartium ribicola Fischer. The fungus completes its life cycle by growing on the leaves of plants of the Ribes genus, which includes currants and gooseberries. The disease is transmitted by windblown spores that enter the tree through its needles. The disease spreads along the branch from the infected needle until it reaches the main stem; it girdles the stem and the tree dies.

The standard treatment in Ontario in the 1950s and 1960s to control blister rust was to eradicate Ribes on an intensive scale in selected areas where white pine was being managed. Currently, however, with a few exceptions, most Ribes control work is confined to the vicinity of provincial tree nurseries to ensure that white pine shipping stock is free of disease.

If infection occurs on outplanted white pine stock from seedlings raised in nurseries which are free of blister rust infection, it is likely to be in the form of a lateral branch canker rather than a stem canker. With intensive management the disease can be controlled by low-branch pruning.

The main reason for the reduction in Ribes control work in Ontario is the banning of 2,4,5-T which means that Ribes control must be done exclusively by hand pulling, a much costlier method than chemical application. Other reasons for the reduction in Ribes control work are the difficulty in obtaining a satisfactory

level of control and the general feeling that in the eastern part of the province the losses are not high enough to warrant the expenditure.

Although blister rust hazard zones are recognized in parts of the United States, there is no formalized policy in Ontario to indicate where it is safe to manage pine. However, there is undoubtedly knowledge available within the district or management unit that has been assembled over the years to indicate where white pine should or should not be grown. This knowledge may be supplemented with information available in Station Paper #92 from the Lake States Forest Experiment Station entitled Growing White Pine in the Lake States to Avoid Blister Rust (E.P. Van Arsdel, 1961). The article discusses the relationship of temperature and humidity to the incidence of the disease.

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